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Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

This Issue

LPG-ENGINE FUEL and LUBRICANT REQUIREMENTS

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LUBRICATION

A TECHNICAL PUBLICATION DEVOTED TO THE SELECTION AND USE OF LUBRICANTS

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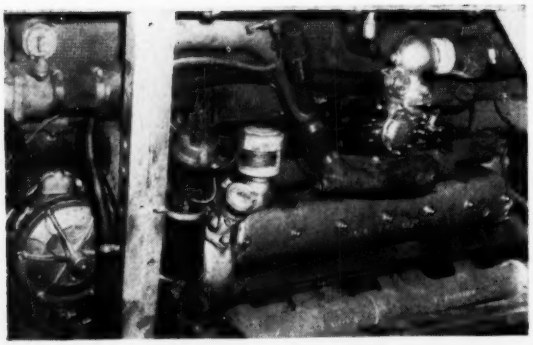
LPG-Engine Fuel and Lubricant Requirements

NATURAL gases and light petroleum hydrocarbons have been used for powering engines for a number of years. Both diesel and gasoline engines have been converted to this type of fuel powering. In the automotive field, engine conversions were reported more than twenty-five years ago. However, in the last five years a large increase in use of LPG has occurred, which in turn has created a wide interest in this subject. The interest was undoubtedly spurred by a bus manufacturer (Fig. 1) whose engine was designed for high compression ratios and was easily modified to utilize LPG. The interest and use of LPG powered engines has also grown in farm tractor (Fig. 2), road truck (Fig. 3), and recently in industrial truck services. (Fig. 4). Many factory built LPG engines are now available and conversion kits can be obtained for practically all makes of automotive engines. Extensive use of LPG also exists in stationary (Fig. 5) and industrial applications. Although these engines are not covered by this article, most of the information presented is applicable. These latter engines are omitted since they are not always operated on automotive type of LPG.

LPG is not new. The lighter hydrocarbons that are normally gases at atmospheric pressure and above freezing temperatures have been used for years as sources of heat – even in internal combustion engines. Although commercial butane and commercial propane used in automotive engines are considered to be similar to gasoline except for methods of handling, a review of their characteristics reveals enough differences to warrant engine modifications to utilize the fuel best. These characteristics and their effect on engine performance are discussed. A review of engine factors and actual test results indicates that consideration should be given to the motor oil used on LPG engines. Motor oil recommendations are included.

The purpose of this article is to present information on the composition, characteristics and specifications of automotive type LPG and engine modifications and engine lubrication requirements when using LPG as the fuel.

An article of this nature may indicate more advantages than disadvantages for the use of LPG. However, it must be remembered that the most suitable fuel for one operation is not necesarily the best selection for another. The choice of the type of fuel powering to be used must be made on the basis of a complete analysis of the particular operation. Many factors are involved such as, type of equipment in use and its expected life, overhaul and service facilities available, type of operation, initial costs, costs of replacements and parts, availability and cost of fuel, and local or area restrictions and regulations. The

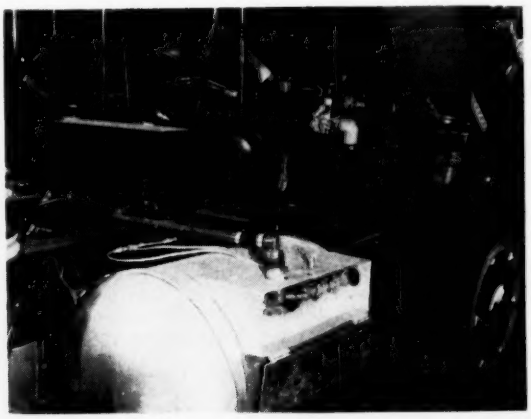


Courtesy Twin Coach Company

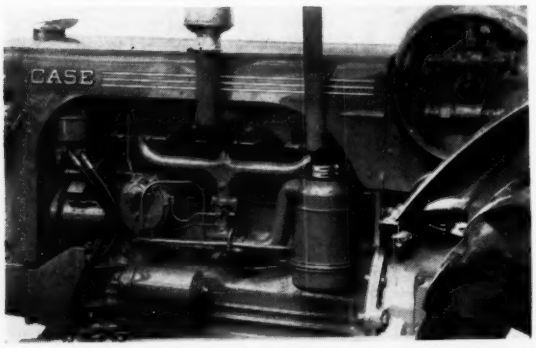
Figure 1 — Transit Type Bus LPG Engine Installation.

Courtesy Kenworth Motor Truck Co.

Courtesy Massey-Harris-Ferguson, Inc.

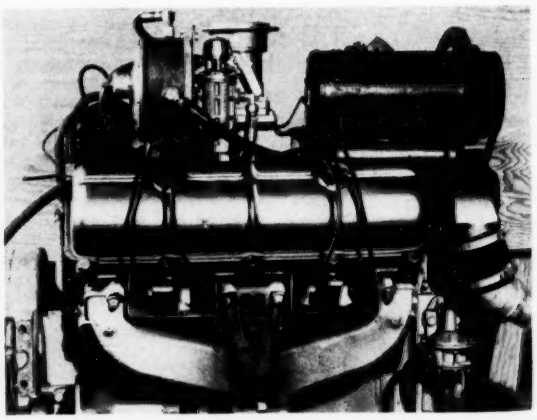


Courtesy Mack Trucks, Inc.



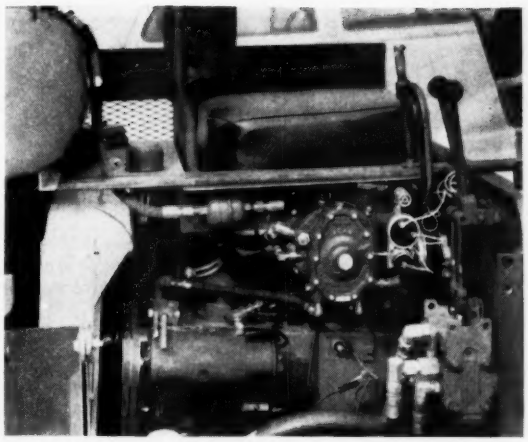
Courtesy J. I. Case Company

Figure 2 — Farm Tractors LPG Powered.



Courtesy Century Gas Equipment Co.

Figure 3 — Truck LPG Engines.



Courtesy Beam Products Manufacturing Co.

Figure 4 — Industrial Truck LPG Engine Installation.

selection of equipment requires considerable discussion far beyond the scope of this article.

At present, the majority of automotive equipment is gasoline powered, with an increasingly small percentage using LPG, while diesel powering is a distant second to gasoline.

The LPG engine is considered to be in the gasoline engine category since it operates in the same manner, although the fuel is handled differently. Also, the engine should be modified to obtain the best performance and utilization of LPG. These modifications will be covered in the subsequent discussion on LPG characteristics. In some cases engines may be converted at low cost so that the operator can derive some particular benefits of LPG without extensive penalties. (Fig. 6)

WHAT IS LPG

LPG — Liquefied Petroleum Gas — is comprised of the C_4 (4 Carbon atoms per molecule) or lighter hydrocarbons that assume a gaseous state at standard atmospheric pressure and above freezing temperatures. Commercial LPG for automotive use is primarily a mixture of either propane and/or propylene and butane and/or butylene with minor amounts of the other gases and perhaps very small amounts of heavier C_5 hydrocarbons.

When these gases are pressurized, they assume a liquid state which is more suitable and economical for handling. The amount of pressurization for liquefication varies with the composition of LPG. These gases as obtained in a natural state and from petroleum refining processes may contain impurities, such as sulfur compounds and other contaminants which may be injurious to engine parts. The engine operator should have some assurance that these contaminants are minimized. This factor has been considered in the specifications for commercial LPG fuels, as shown in Table I. These specifications also consider the factor of constant composition of the fuel since each fuel component has somewhat different characteristics, as may be noted in Table II wherein a comparison of the LPG components, motor gasoline and diesel fuel is made.

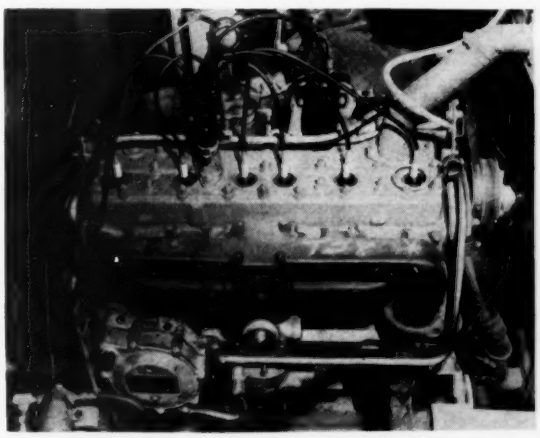
Characteristics That Affect Engine Factors

LPG has different characteristics than either motor gasoline or diesel fuel as shown in Table II. For simplicity, all of the possible components of LPG were not included since their characteristics fall in the range of those of butane and propane. Since LPG is most similar to motor gasoline in application, a best comparison may be made between these two fuels.

LPG boils far below room temperature and is liquid at room temperature only when under pressure. Propane has a boiling point of —44°F., while butane boils at 31°F. At 100°F. an absolute pressure of 185 psi[a] and 53 psi respectively is required

[a] psi—pounds per square inch.

Courtesy Minneapolis-Moline Co.



Courtesy Marvel-Schebler Products Div.

Figure 5 — Industrial, Stationary LPG Engines.

TABLE I

Liquefied Petroleum Gases, Specification
Based on N. G. A. A. Specifications June, 1951

	Commercial Propane	Commercial Butane	Propane-Butane Mixtures
Composition	95% minimum propane and/or propylene free from harmful quantities of deleterious substances.	Approximately 95% minimum butane and/or butylenes free from deleterious substances.	Mixtures of propane and/or propylene and butane and/or butylene predominantly free from deleterious substances.
Vapor Pressure, psi @ 100°F.	215 max.	70 max.	215 max.
Total Sulfur, (lamp) grains/100 cu. ft.	15 max.	15 max.	15 max.
H_2S (Hydrogen Sulfide)	None	None	None
Corrosion, Copper Strip 3 Hours @ 122°F.	Negative	Negative	Negative
Water, % (Cobalt Bromide)	None	None	None
95% Boiling Point (95% Evaporated) °F. @ 740 mm Hg barometer	—	34 max.	34 max.
Designation	—	—	By vapor pressure at 100°F. in psi gage. (Within +0 lbs. —5 lbs. of vapor pressure specified)
Residue, % (Mercury Freeze Test)	2 max.	—	—

to keep these hydrocarbons in a liquid state. A pressure-temperature chart for different blends of these two fuels is shown as Fig. 7. Motor gasoline boils in the range of 90°F. to 420°F. and is a liquid at standard atmospheric pressure.

An operating problem due to fuel composition can occur when a primarily butane fuel is used at temperatures below 32°F. Since butane is in a liquid state at these temperatures, the fuel will not vaporize quickly enough to respond to engine demands. Heating the fuel would appear to be a solution to the problem; however, due to the possible hazards of heating LPG, it is not permitted in automotive service. A more practical solution is to include lighter hydrocarbons, such as propane, in the fuel to lower the boiling point and to increase vaporization of the fuel.

Automotive LPG Fuel System

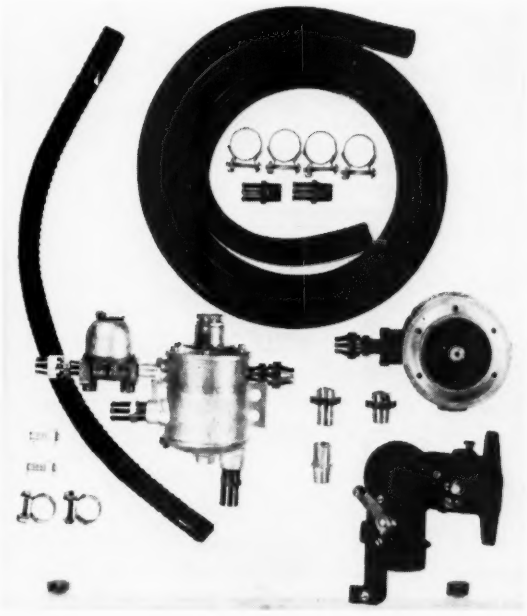
Since LPG is in a gaseous state at standard atmospheric pressure and temperatures above 32°F., some means must be provided for getting the fuel from its pressurized liquid state in the fuel tank to slightly below atmospheric pressure in the manifold of the engine.

A typical automotive vehicle LPG fuel system compared to a gasoline system is shown as Fig. 8. Fig. 9 shows a schematic drawing of an LPG installation. The transfer of the fuel from the tank to a small engine can be done by taking vapors directly from the fuel tank to the carburetor; however, this method has limitations. The method usually used consists of four stages. A tank pressure of 20 to 200 psi gage must first be reduced to a regulated

TABLE II

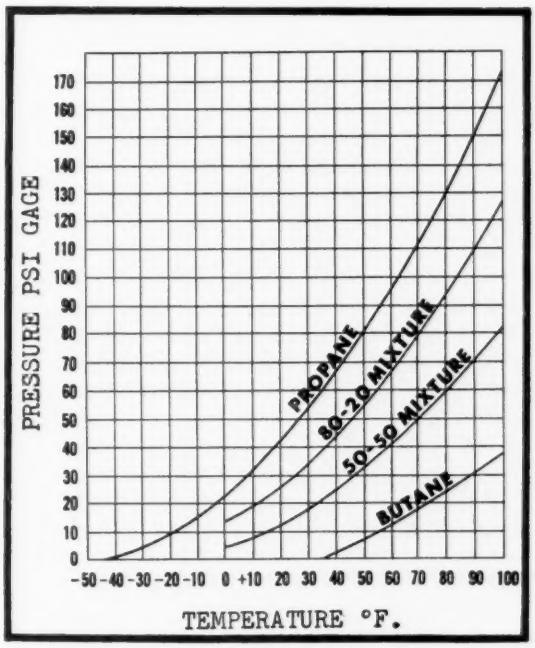
Typical Characteristics of Automotive Fuels

Name	Propane	Butane	Motor Gasoline	Kerosine	Diesel Fuel
Gravity °API	147	111	60	42	35
Boiling Point °F.	—44	31	90-420	300-500	350-675
Vapor Pressure @ 100°F. psi abs.	185	53	6-15 (Reid)	Less than 1.0 (Reid)	Less than 1.0 (Reid)
Specific Gravity 60/60 °F.	0.508	0.584	0.74	0.82	0.85
Specific Weight @ 60°F. lb./gal.	4.23	4.86	6.16	6.79	7.08
Lower Heating Value					
BTU/lb.	19,670	19,470	18,900	18,560	18,390
BTU/gal.	83,340	94,670	116,400	126,200	130,300
Octane No.					
Research	100 + 1.9 ml-tel	94	85-100 +	—	—
Motor	97	90	75-95	—	—
Stiochiometric Air Fuel Ratio	15.7:1	15.5:1	14.7:1	—	—



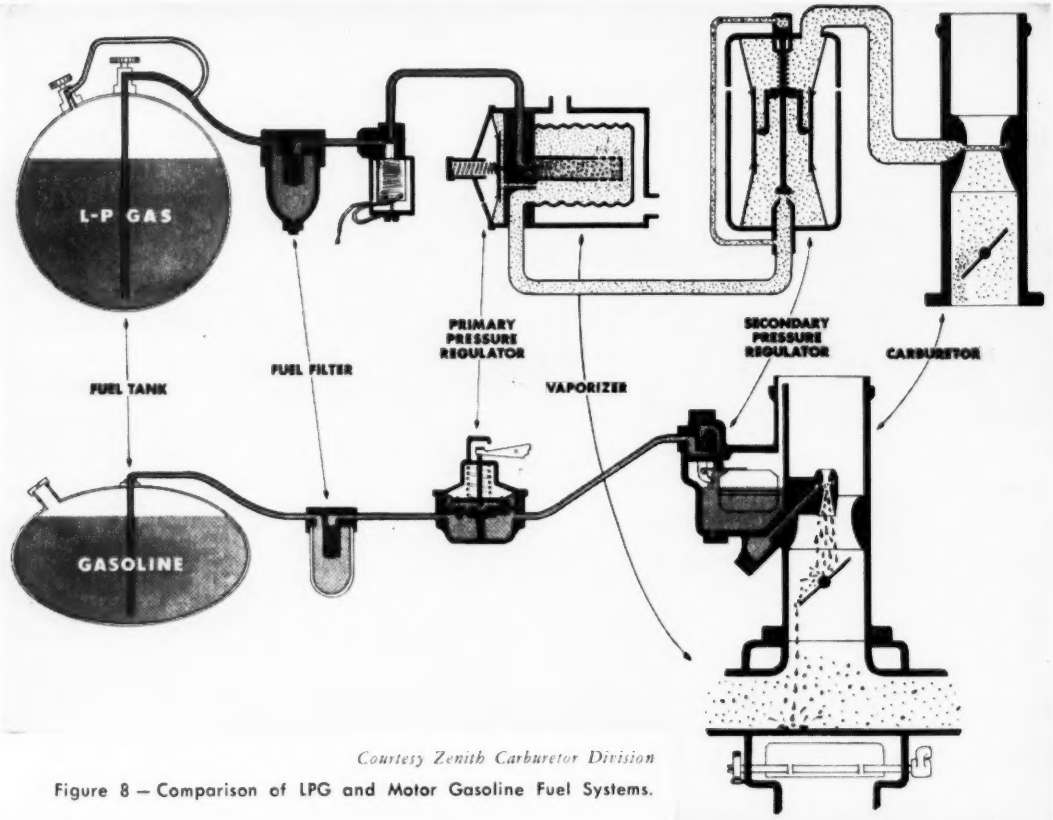
Courtesy J&S Carburetor Co.

Figure 6 — LPG Conversion Kit for Farm Tractor (less tank and tubing).



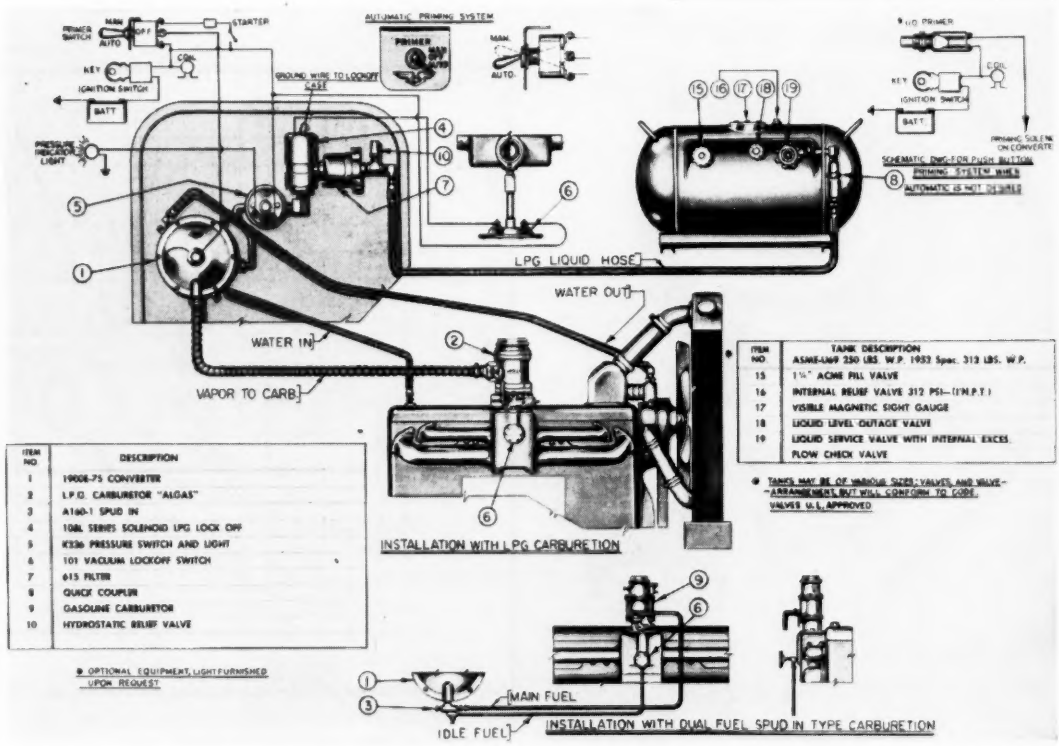
Courtesy Zenith Carburetor Division

Figure 7 — Butane-Propane Vapor Pressure Chart.



Courtesy Zenith Carburetor Division

Figure 8 – Comparison of LPG and Motor Gasoline Fuel Systems.



ITEM NO.	DESCRIPTION
1	19008-75 CONVERTER
2	L.P.G. CARBURETOR "ALGAS"
3	A160-1 SPUD IN
4	108L SERIES SOLENOID LPG LOCK OFF
5	K336 PRESSURE SWITCH AND LIGHT
6	101 VACUUM LOCKOFF SWITCH
7	615 FILTER
8	QUICK COUPLER
9	GASOLINE CARBURETOR
10	HYDROSTATIC RELIEF VALVE

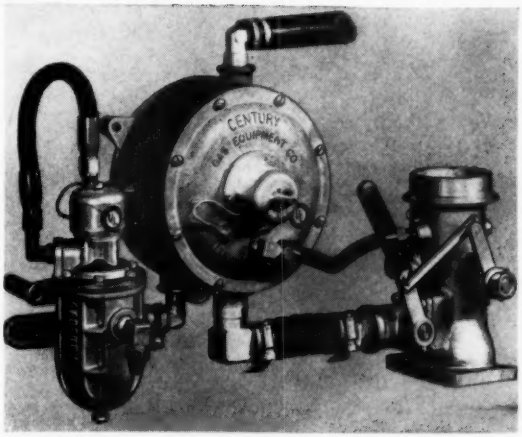
* OPTIONAL EQUIPMENT, LIGHT FURNISHED UPON REQUEST

ITEM NO.	TANK DESCRIPTION ASME-U69 250 LBS. W.P. 1952 Spec. 312 LBS. W.P.
15	1¼" ACME FILL VALVE
16	INTERNAL RELIEF VALVE 312 PSI–(1¼ P.T.)
17	VISIBLE MAGNETIC SIGHT GAUGE
18	LIQUID LEVEL OUTAGE VALVE
19	LIQUID SERVICE VALVE WITH INTERNAL EXCESS FLOW CHECK VALVE

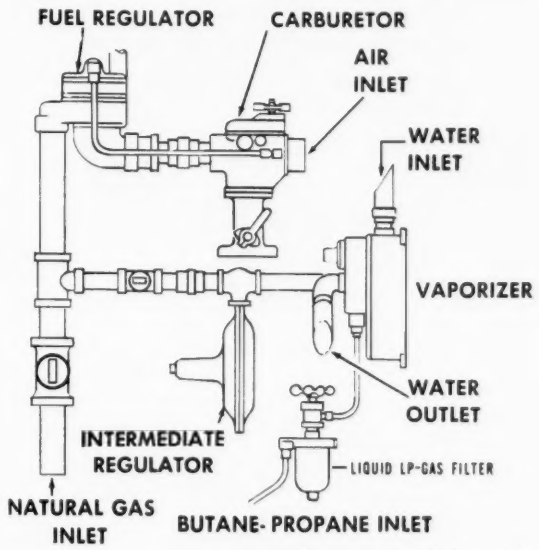
* TANKS MAY BE OF VARIOUS SIZES, VALVES AND VALVE ARRANGEMENTS BUT WILL CONFORM TO CODE. VALVES U.L. APPROVED

Figure 9 – Schematic Drawing of LPG Fuel System Installation.

Courtesy American Liquid Gas Corp.



Courtesy Century Gas Equipment Co.



Courtesy Ensign Carburetor Co.

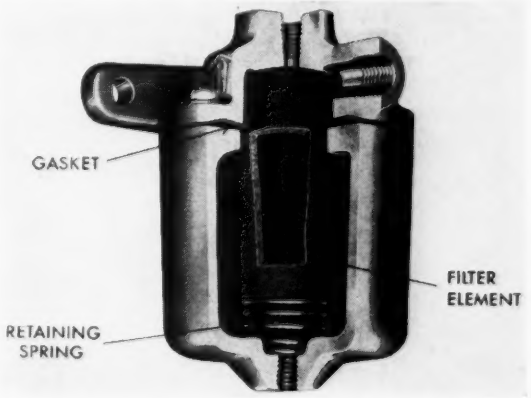
Figure 10 — LPG Fuel Systems.

5 to 15 psi gage. The fuel is then allowed to vaporize rapidly. In expanding and vaporizing rapidly, the fuel absorbs large quantities of heat, thereby causing a refrigerating effect which can freeze the mechanisms involved. To overcome this refrigerating effect, the vaporizer must be heated. This is accomplished by means of a heat exchanger utilizing the engine coolant. To assure sufficient heat for the vaporizer, high engine coolant temperatures (160-180°F.) should be maintained. The regulator consisting of two valves and a heat exchanger is sometimes considered to be a part of the LPG carburetion system. The final regulator reduces the pressure of the vaporized gas to slightly below atmospheric pressure. This regulator must shut off fuel before it reaches atmospheric pressure to prevent leakage and must be designed to permit vaporized gas to flow instantly to the carburetor in metered volumes to conform to every engine demand. The remainder of the system is a simple carburetor containing a venturi to meter the fuel to the engine proportional to air flow, an economizer to lean out air-fuel ratios at part throttle, and a starting device the equivalent of a choke in a motor gasoline carburetor. It is quite obvious that some of these four stages may be combined so that more than one step is accomplished in one piece of mechanism. Typical LPG fuel systems and component parts are shown as Fig. 10 through Fig. 13.

Since the fuel system can encounter high pressures, fuel tanks and fuel lines must be made especially for LPG. If definite codes are not established in any particular area, fuel tanks, lines, valves and accessories should be built in accordance with the API-ASME Code for 250 lbs. tanks. For more specific information on this subject the reader may refer to the National Board of Fire Underwriters pamphlet No. 58[b] which covers storage and handling of LPG.

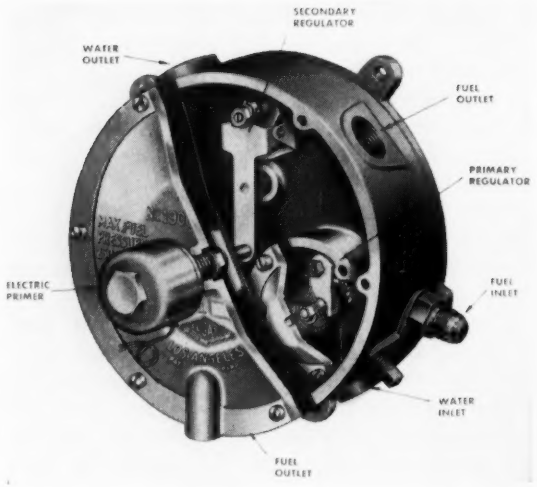
LPG tanks should never be filled 100%. A 10%, or preferrably 20%, vapor space must be allowed for expansion of the fuel with temperature increases. The 20% vapor space is a definite requirement if temperature variations may approach a 100°F. spread. Some manufacturers include a "full valve" to indicate when the expansion space has been reached in filling. When filling this type of tank, vapor is allowed to escape through the "full valve." When liquid fuel starts to drain, filling should be stopped as the expansion space has been reached. Another manufacturer includes an inner tank, called an outage tank, with the fill valve arranged to seal off this expansion space during tank filling. Some tank arrangements and control valves are shown as Fig. 14 through 16.

[b] Standards of the National Board of Fire Underwriters for the Storage and Handling of Liquefied Petroleum Gases as recommended by the National Fire Protection Association, 85 John Street, New York 38, N. Y.; 222 West Adams Street, Chicago 6, Ill.; 465 California Street, San Francisco 4, Calif.

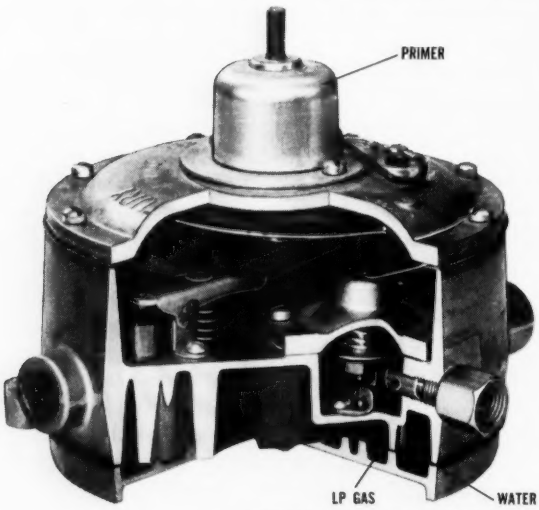


Courtesy American Liquid Gas Corp.

Figure 11 — LPG Fuel Filter.



Courtesy American Liquid Gas Corp.



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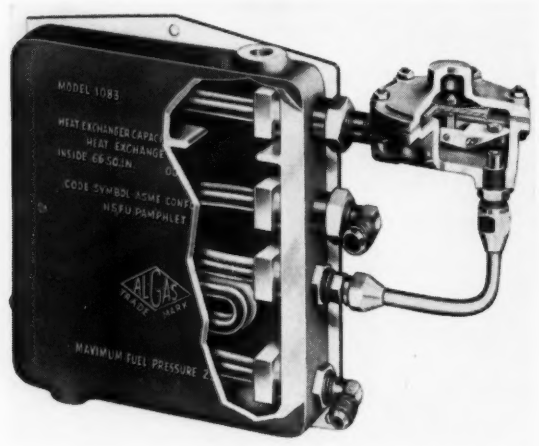
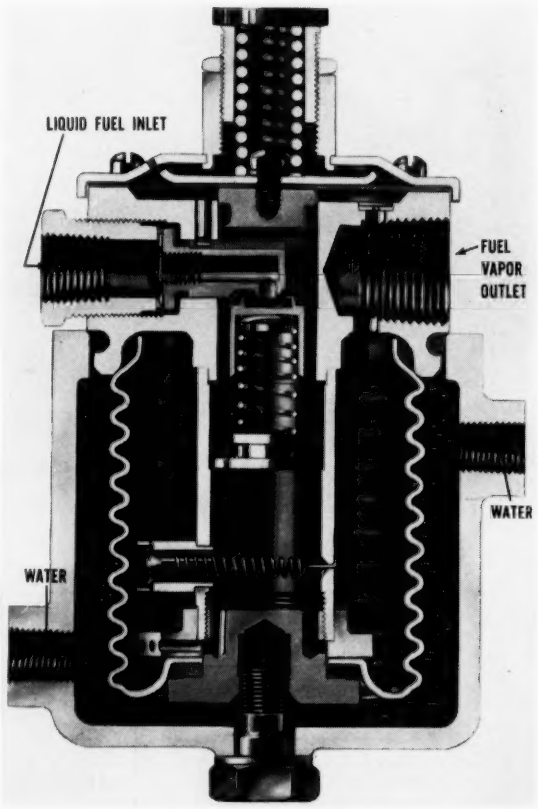
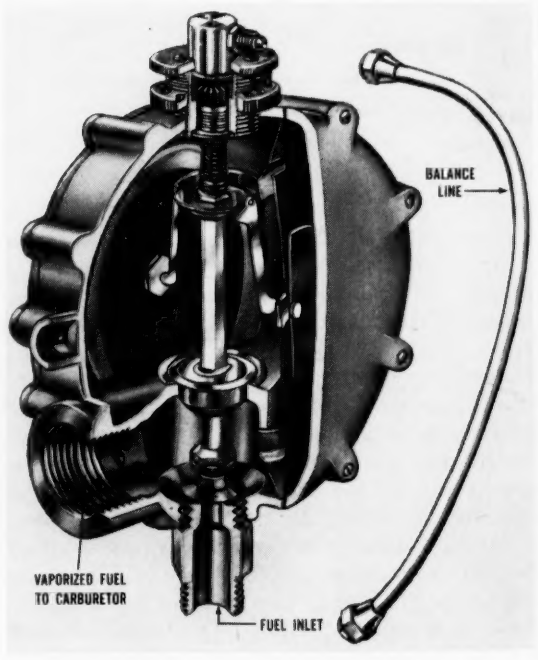


Courtesy American Liquid Gas Corp.

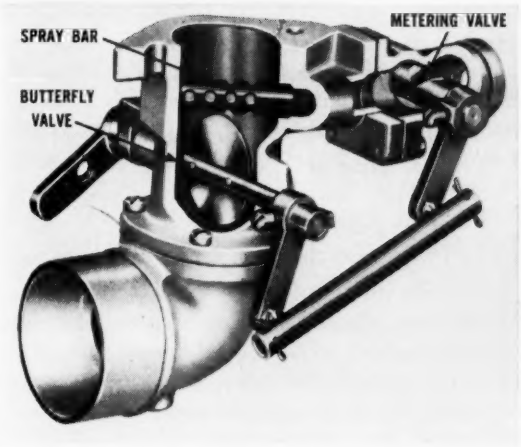


Courtesy Zenith Carburetor Division



Courtesy Zenith Carburetor Division

Fig. 12 — LPG Regulators and Vaporizers.



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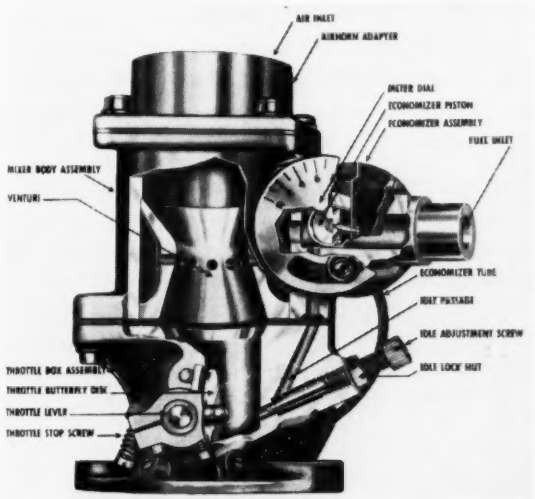


Courtesy American Liquid Gas Corp.

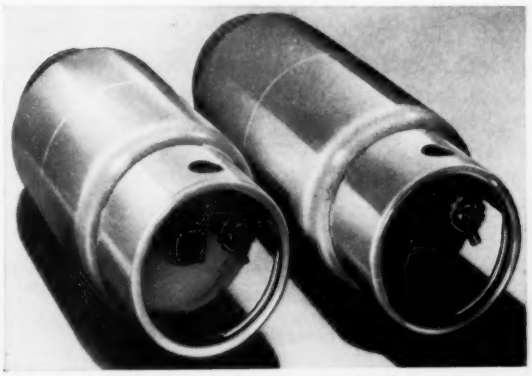
Figure 13 — LPG Carburetors.

Special equipment is, of course, required for storing LPG at the refueling point and for fueling the vehicle tank. This high pressure pump system usually includes a vapor return line to minimize pumping costs and to eliminate fuel vapor leaks to the surrounding area. Precautions should be taken to minimize fuel leaks and to prevent accumulation of LPG vapor where it might be ignited accidently. Also, LPG vapor is heavier than gasoline vapor and air and tends to accumulate in unventilated low areas. This is a dangerous condition even though the flammability of LPG is narrower than that of motor gasoline. Some precautions in the handling of LPG equipment are shown as Table III.

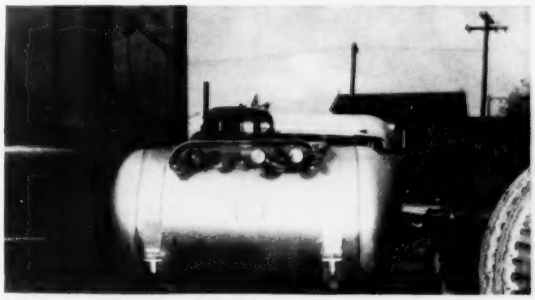
Engine Performance

The intake manifold of an LPG engine contains a mixture of LPG vapor and air, while that of a gasoline engine contains air, gasoline vapor, gasoline mist and liquid gasoline. The LPG vapor necessary to charge a single cylinder for one power stroke occupies considerably more space than gasoline for one power stroke. The area of the intake ports of an engine determines the volume of fuel-air mixture it can handle, so that the greater volume of the gaseous LPG reduces the amount of air the engine can take per stroke, as compared to gasoline. Fig. 17 shows the volumetric efficiency[e] of an engine on both LPG and gasoline showing the reduction in air handling capacity when using LPG as the fuel. Since engine power is proportional to air consumption, a given size LPG engine produces less power than when using gasoline in

[e] $\frac{\text{Weight of air actually taken in} \times 100}{\text{Weight of air required to fill cylinder to atmospheric pressure}}$



Courtesy Pressed Steel Tank Co.



Courtesy Kenworth Motor Truck Co.

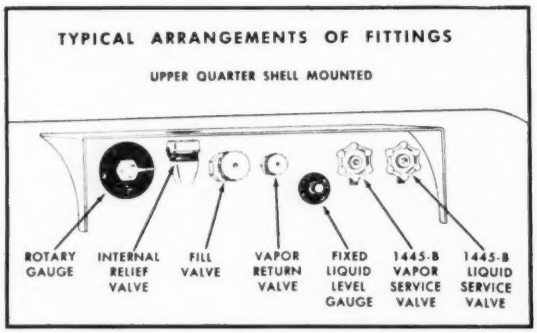
Courtesy North Texas Tank Co.

Figure 14 — LPG Tanks.

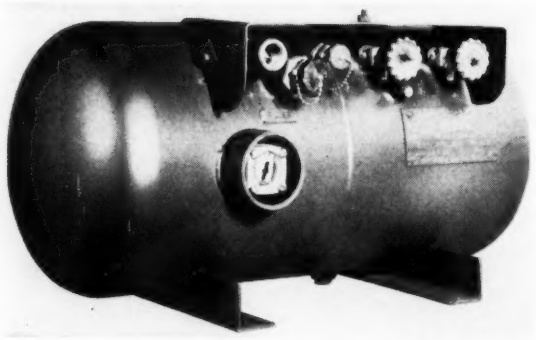
TABLE III

Safety Precautions

1. Operate engine in well ventilated areas.
2. Engine and fuel system repair work should be done in well ventilated area to avoid low pockets such as unventilated pits.
3. Don't store vehicles over unventilated pits (garaging).
4. Shut off fuel tank valve and run engine out of fuel before doing engine work.
5. Avoid open flames near repair work, use danger signs and prohibit smoking in area.
6. Ventilate engine compartment after servicing.
7. On accident vehicles, check for leaks before inside storage.
8. Work on fuel tank should be done by specialized people.
9. Never use LPG for cleaning parts, blowing horns, inflating tires, cleaning out cab and other uses not intended for LPG and where there is no control of the fuel.
10. After repairs check for leaks – smell or soapy water, NEVER A FLAME.
11. If possible use a vapor return line when refueling.
12. Do not replace high pressure fittings with other than high pressure parts.
13. Fuel system should have a safety shut off controlled by engine ignition switch.
14. Have CO_2 or dry powder fire extinguisher available.
15. Never vent fuel system in an enclosed area.
16. Drain the fuel system prior to storing vehicles for extended periods.



Courtesy Ensign Carburetor Co.



Courtesy Pressed Steel Tank Co.

Figure 15 – LPG Tank Fittings.

the same engine, providing other conditions are constant.

To combat this deficiency, LPG engines should be designed with intake and exhaust manifolds well separated to keep the incoming air as cool as possible, thus maintaining high charge density. In converting gasoline engines to LPG operation, manifold "hot spots" used to aid in vaporizing liquid gasoline must be inactivated as far as possible. The engine used to develop the data shown in Fig. 17 had the intake and exhaust manifolds separated by a steel plate at the location of the "hot spot" during LPG operation.

A second method of regaining power lost by inducting gaseous LPG instead of gasoline liquid and vapor into the cylinders is to use a higher compression ratio with LPG (assuming the engine is of the type satisfied by lower octane motor gasolines). Some commercial propane engines use compression ratios in the neighborhood of 10:1.

The compression ratio of a gasoline engine may be raised by planing the cylinder head or by means of special pistons or cylinder heads. Care should be exercised to assure that pistons and valves do not interfere when compression ratios are increased. Many existing gasoline engines cannot be increased easily more than one compression ratio. It is strongly stressed that, before an attempt is made to increase the compression ratio of an engine more than one compression ratio, the engine manufacturer should

be consulted in regards to the advisability of the proposed modification, since higher compression ratios will increase the stressing of engine parts.

Fig. 18 shows the torque output of an engine on motor gasoline at 6.6:1 and 7.1:1 compression ratio and with two different LPG carburetor systems at 7.1:1 compression ratio. It may be noted that the torque was greater with gasoline at 6.6:1 compression ratio than with LPG at 7.1:1 compression ratio. The lowest torque was attained with gasoline and an economy type carburetor which restricted air flow to the engine through a smaller size venturi.

Fig. 19 compares brake specific fuel consumption for the engine performance noted above. While the brake specific fuel consumption of this converted engine using LPG was in the range of the gasoline version, both were inferior to the brake specific fuel consumption (also shown in Fig. 19) of a commercial engine designed for LPG having a 10:1 compression ratio and with the intake and exhaust manifolds well separated.

Burning Rate

Because LPG has burning characteristics different from gasoline, it requires different spark timing from gasoline for best performance. Fig. 20 shows full throttle torque of the converted engine at various engine speeds and static spark settings using the engine's standard gasoline distributor and LPG fuel. A line is also plotted showing maximum power static spark settings with a gasoline distributor while using motor gasoline. It may be noted that best power using LPG fuel was at a more advanced spark setting at low speeds and a more retarded spark setting at high speeds than with gasoline.

Fig. 21 shows actual spark timing over the engine speed range with an LPG distributor on a commercial engine as compared to specifications for the distributor for the gasoline version of this engine.

TABLE IV
Ignition Temperatures °F.*

Hydrocarbon	Atmospheric Pressure	200 psi abs
Propane	950-1080	700
Butane	890-1020	670
Gasoline (Regular Grade)	860	560

* Butane-Propane Power Manual

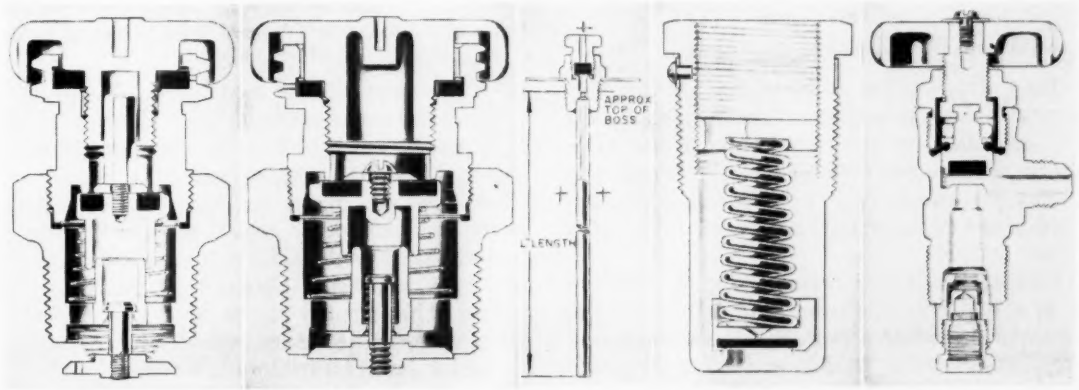
The LPG distributor furnished more spark advance at low speeds and less at high speeds than the gasoline distributor, indicating a characteristic similar to that noted in Fig. 20.

During the course of LPG testing in a converted gasoline engine, more exhaust valve and spark plug burning was noted when using LPG compared to gasoline as the fuel. Special valves and spark plugs would of course be required to eliminate or reduce these burning difficulties in an LPG powered engine. Also LPG has a higher ignition temperature than motor gasoline, as noted in Table IV; therefore, a hotter spark is required.

Hotter combustion temperatures with LPG require the use of a colder spark plug, better valve material and improved valve condition.

Density

Although propane and butane have higher heating values per pound of fuel than motor gasoline, gasoline has more pounds per gallon or is denser than LPG. At the same compression ratio in a given engine at optimum conditions for each fuel, it might be expected that for the same power more motor gasoline than LPG is required on a weight (pound) basis. However, since slightly different air-fuel ratios are required and a difference in air volumetric efficiency exists, power per pound of fuel is approximately equivalent for these fuels. On



Courtesy Fisher Governor Co.

Figure 16 – LPG Tank Controls.

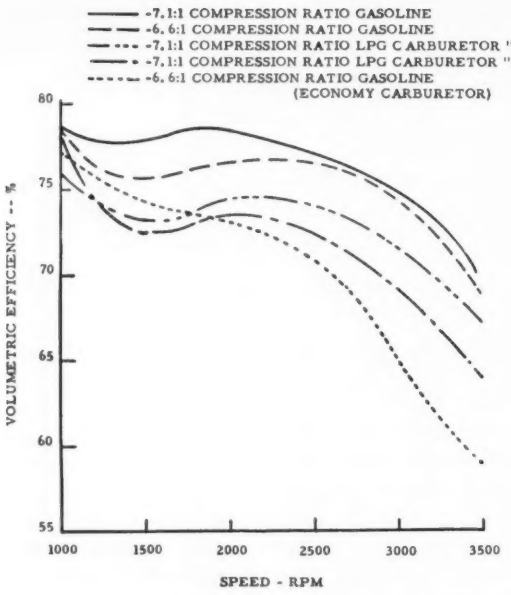


Figure 17 — Volumetric Efficiencies vs. Speed.

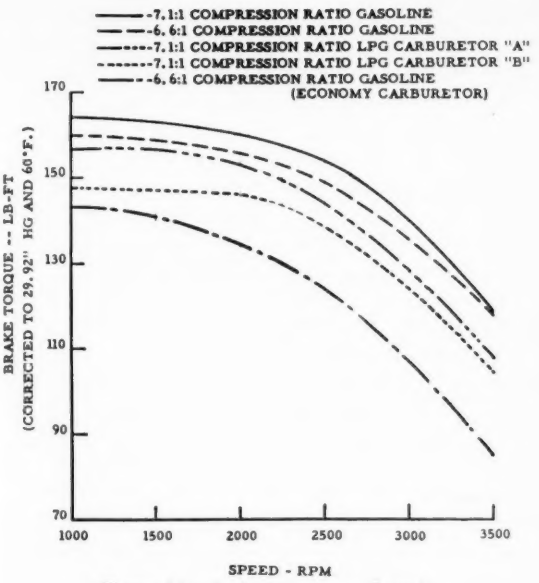


Figure 18 — Brake Torque vs. Speed.

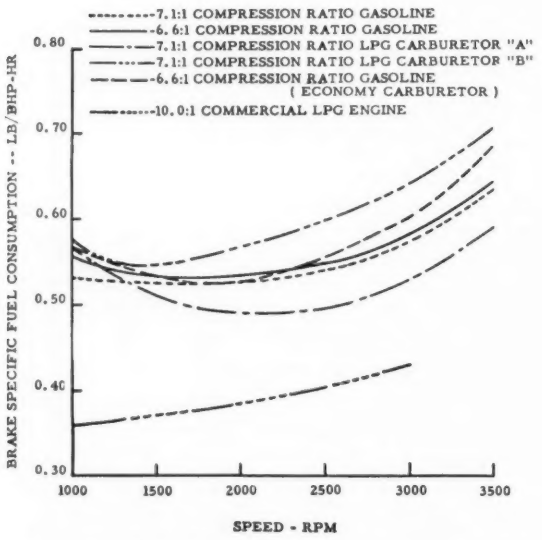


Figure 19 — Brake Specific Fuel Consumption vs. Speed.

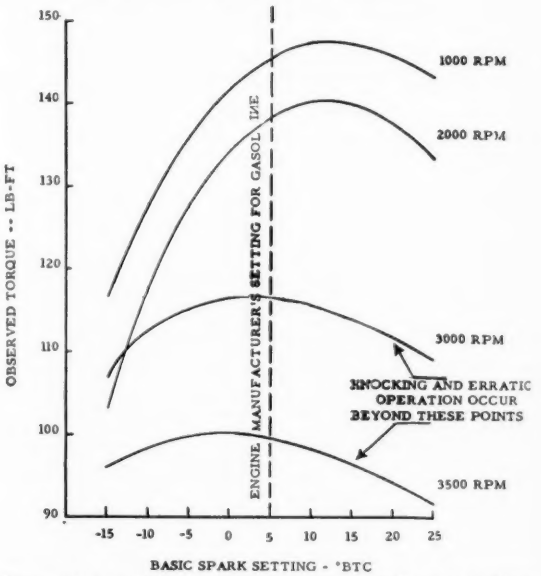


Figure 20 — Full Throttle Torque vs. Spark Setting at Various Engine Speeds.

the basis of power per gallon of fuel, motor gasoline would show an economy advantage of possibly 25% depending on the composition of the LPG. In service, fuel consumption is usually measured on a miles per gallon basis and therefore gasoline would show an economy advantage in a given engine.

Utilizing the higher octane rating of LPG by use of a higher compression ratio to obtain more power per pound of fuel makes it possible to improve LPG economy, so that on a miles per gallon basis it is about equivalent to that of motor gasoline. As the octane of motor gasoline approaches that of LPG, this compensating modification decreases.

Some fuel consumption data are shown in Table V. It may be noted that for the converted gasoline engine LPG fuel consumption on a pound and gallon basis was higher than either motor gasoline in the same engine or typical gasoline and diesel fuel consumption rates. Maximum utilization of the LPG was not being obtained in the converted engine. This justifies claims of engine manufacturers who advise against conversion of existing engines if best performance is desired.

By using a high compression ratio and proper manifolding, the commercial LPG engine showed

TABLE V

Fuel Consumption Comparison

Type Fuel	Engine Size	Fuel Economy: Brake Specific lb/BHP—Hr	Fuel Economy: Over-All Gal/BHP—Hr	Fuel Density lb/Gal
Diesel	Less than 4 inch bore*	<0.51	0.073	7.1
	More than 4 inch bore*	>0.45	0.064	7.1
Gasoline	Less than 4 inch bore*	<0.57	0.093	6.2
	More than 4 inch bore*	>0.56	0.091	6.2
	Test engine			
	3½ inch bore			
	6.6:1 C.R.	0.54	0.088	6.2
	7.1:1 C.R.	0.53	0.086	6.2
LPG	Test engine			
	3½ inch bore			
	7.1:1 C.R.	0.608	0.124-0.143	4.2
	Commercial engine			
	4¼ inch bore			
	10.0:1 C.R.	0.395	0.093	4.2

* Kent's Handbook

C.R.—Compression Ratio

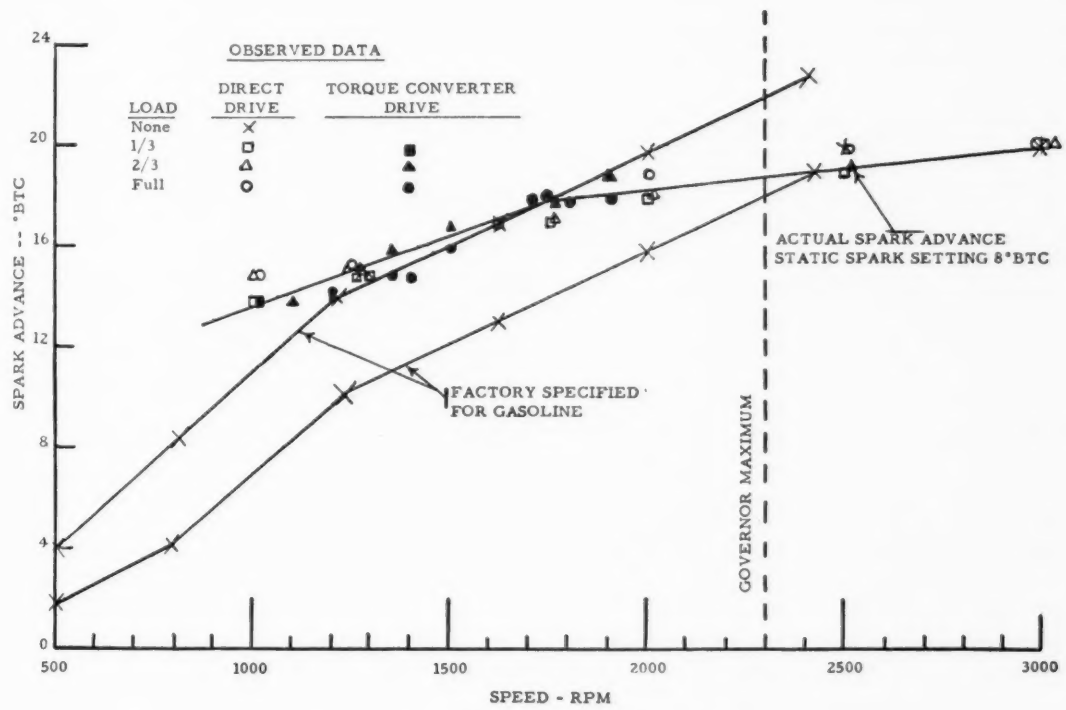


Fig. 21 — Spark Timing Over Engine Speed Range.

TABLE VI

Fuel Consumption Comparison

Minneapolis-Moline Model 283 Engine

Fuel Powering	Compression Ratio	Gallons of Fuel Per 100 HP-Hrs at Throttle Setting				
		OP Max.	Rated	3/4	1/2	1/3
Propane	7.9:1	9.6	9.9	10.4	11.5	14.0
Butane	7.9:1	8.5	8.8	9.5	11.0	13.2
Propane	6.3:1	10.8	11.0	11.8	13.2	16.8
Butane	6.3:1	9.9	10.4	10.4	11.6	14.9
Gasoline	6.3:1	8.1	8.2	8.9	10.5	12.8

Courtesy Minneapolis-Moline Co.

low brake specific fuel consumption – even lower than that indicated for a typical diesel engine. On a volume (gallons) basis, consumption was equivalent to that of a typical gasoline engine but greater than that of a typical diesel engine.

Tables VI and VII and Fig. 22 show fuel consumption comparisons on commercially available equipment. It may be noted that the results confirm the discussion above on fuel economy.

LPG ENGINE LUBRICANT REQUIREMENTS

Since LPG is a gas at the engine carburetor, it would be expected that adequate mixing with engine intake air should occur, and if the mixture is properly proportioned, complete combustion should result if other engine conditions are reasonably correct. Also, if some incomplete burning is experienced, the unburned fuel and combustion products being in a gaseous state (with proper engine coolant temperatures) should be exhausted from the engine. Under these conditions it seems that there should be no engine deposits from the fuel, no cylinder washing as experienced with gasoline and diesel fuel and no crankcase lubricant contamination. It is obviously easy to assume that under these conditions a straight mineral oil should be adequate for the engine and/or oil drain periods can be either extended or eliminated. A closer look at the factors of an operating engine and some actual engine test data will show this assumption to be wrong.

TABLE VII

Fuel Consumption Comparison

John Deere Tractors

Fuel	Max. Power Belt HP	Compression Ratio	Fuel Consumption	
			Lbs/BHP–Hr	Gal/Hr
Model 50				
Gasoline	30.97	5.8:1	0.52	2.4
All Fuel	25.75	—	0.60	2.1
LPG	32.29	8.0:1	0.47	3.3
Model 160				
Gasoline	41.57	5.8:1	0.54	3.4
All Fuel	33.26	—	0.61	2.8
LPG	42.24	7.3:1	0.46	4.3
Model 70				
Gasoline	50.35	6.1:1	0.51	3.9
All Fuel	44.96	4.5:1	0.60	3.6
LPG	51.97	7.3:1	0.44	5.0

Courtesy Deere Manufacturing Co.

Low Temperature Engine Operation

It is well known in automotive service that under low temperature engine operation, that is, stop and go driving and short trips when the engine does not have an opportunity to reach prescribed operating temperatures, undesirable engine deposits are formed. It has been determined that these deposits originate primarily from combustion products that reach the crankcase. The lubricant is not exposed to high tempertures sufficiently to contribute to the formation of engine deposits, particularly, if the oil is either a highly refined product and/or inhibited against oxidation. Under this type of operation it would be expected that LPG powering would not result in low temperature engine deposits.

A full scale engine was operated following a standardized laboratory engine test[d] that simulates low temperature engine service, using commercial propane and a highly refined straight mineral oil. During the test, freezing difficulties were experienced with the fuel vaporizer. At the end of the test engine parts were free of significant amounts of deposit.

Under this type of operation, a well refined straight mineral oil adequately lubricated the engine. However, this type of operation can not be tolerated in LPG service since sufficient engine coolant heat is not available to compensate for the refrigerating effect in the vaporizer, resulting in poor engine power performance.

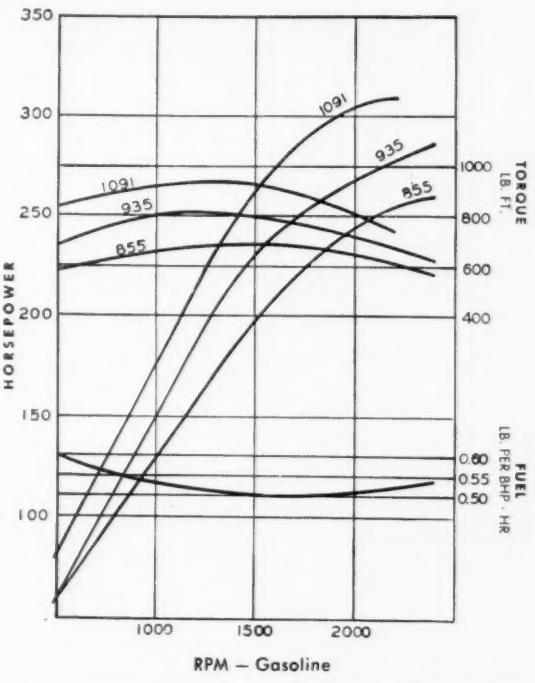
High Temperature Engine Operation

It has been well established that under high temperature engine conditions, heavy duty field service, both the fuel combustion products and the lubricant contribute to engine deposits and bearing corrosion when corrodible bearings are used. Naphthene base oils, under high temperature conditions, increase rapidly in viscosity and form engine deposits. Paraffin base oils oxidize to form materials that are corrosive to engine bearings, particularly those of the copper-lead variety.

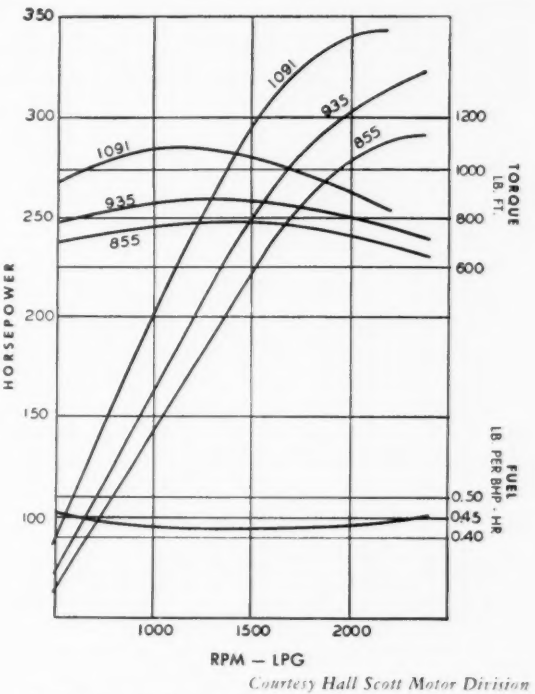
Laboratory engine tests were conducted following a standardized procedure[e] which simulates some phases of heavy duty service, using an LPG powered engine. Some of the results obtained are shown in Table VIII. It may be noted that by using a highly refined paraffinic oil, engine deposits, particularly on pistons, and severe copper lead bearing corrosion were experienced. It was expected basis experience that with a straight mineral naphthenic base oil sufficient engine deposits would have been formed to either prevent appropriate evaluation of the results or to seize the engine.

A heavy duty type oil, which was very satisfactory with gasoline, reduced piston deposits (which in

[d] CRC—FL-2 Procedure.
[e] CRC—L-4 Procedure.



Engine	Compression Ratio Gasoline	LPG
1091	6.4:1	9.0:1
935	6.4:1	9.0:1
855	6.0:1	9.0:1



Courtesy Hall Scott Motor Division

Figure 22 — LPG and Gasoline Performance Curves.

TABLE VIII
Copper Lead Bearing Corrosion
(CRC-L-4 Tests)

Oil	Commercial LPG: Highly Refined Straight Mineral SAE 30	Commercial LPG: MIL-O-2104 Oxidation Stability SAE 30	Gasoline, L-4 Fuel: MIL-L-2104A Oxidation Stability SAE 30
Cleanliness Rating			
Piston*	8.2	9.5	9.0
Overall**	90	90	89
Bearing Corrosion Grams/2 whole bearings	8.373	2.366	0.180
Neutralization No. increase	5.4	3.2	2.2
Viscosity SUS @ 210°F. increase	36	6.8	3

* 10 = Completely Clean
** 100 = Completely Clean

the straight mineral oil test may have been due to both fuel and oil) but did not satisfactorily reduce bearing corrosion. Other heavy duty high quality motor oils and higher detergency level diesel engine oils have been found to be satisfactory in this test. It is obvious from these results that a straight mineral oil in LPG powered heavy duty service engines would not be satisfactory and some compounded oils might also be unsatisfactory.

Crankcase Lubricant Viscosity Increase

Normally little or no crankcase dilution is encountered in LPG engines, therefore, when the crankcase lubricant contacts hot engine parts, the lighter ends of the oil evaporate. The result is an increase in viscosity of the crankcase oil with use.

To maintain the crankcase oil viscosity recommended by the engine manufacturer, the above effect is easily counteracted by using one SAE viscosity grade lighter oil for makeup purposes. The same type of oil as originally charged to the crankcase should be used for makeup.

Crankcase Contamination — Abrasive

The best maintained engines accumulate abrasive materials such as dirt, dust and wear metals which oil filters do not completely remove. These contaminants increase the wear rate of engine parts thereby shortening engine life. The best way to remove these undesirable materials is by changing oil periodically, preferably while the oil is hot and as soon as possible after the engine is shut down.

Crankcase Oil Recommendation

From the above data and information, it is obvious that even the highest quality straight mineral oils are not satisfactory for LPG powered engines under all conditions of operation. For best operation Supplement I quality oils should be used, although there are many applications where the lower detergency heavy duty quality oils will perform with complete success. There does not seem to be a need for higher quality level oils than Supplement I in automotive LPG engines

None of the major LPG equipment manufacturers are recommending straight mineral oils for their engines. Most recommendations are for API service designation MM or MS and MS or DG for heavy duty service. Some designate MIL-L-2104A quality oils.

CONCLUSION

Although LPG appears to be closely related to gasoline, its nature and characteristics are such that for best performance and utilization of the fuel an engine specifically designed for LPG should be used. There are many engine applications, however, where a properly converted engine is sufficient to let the operator benefit from some particular advantages of LPG.

The continuing trend of increasing motor gasoline octane value may soon minimize the octane advantage of LPG.

As in other engines, LPG engines should be properly maintained and lubricated with sufficiently high quality motor oils to obtain maximum engine life.

ACKNOWLEDGEMENT

Most LPG equipment manufacturers were contacted for information to prepare this article. In view of the large volume and in some cases duplication of material received, it was difficult to equitably select items from all of this generous response; therefore, the information and photographs selected were picked at random during the preparation of the article. The cooperation of all suppliers is hereby gratefully acknowledged.

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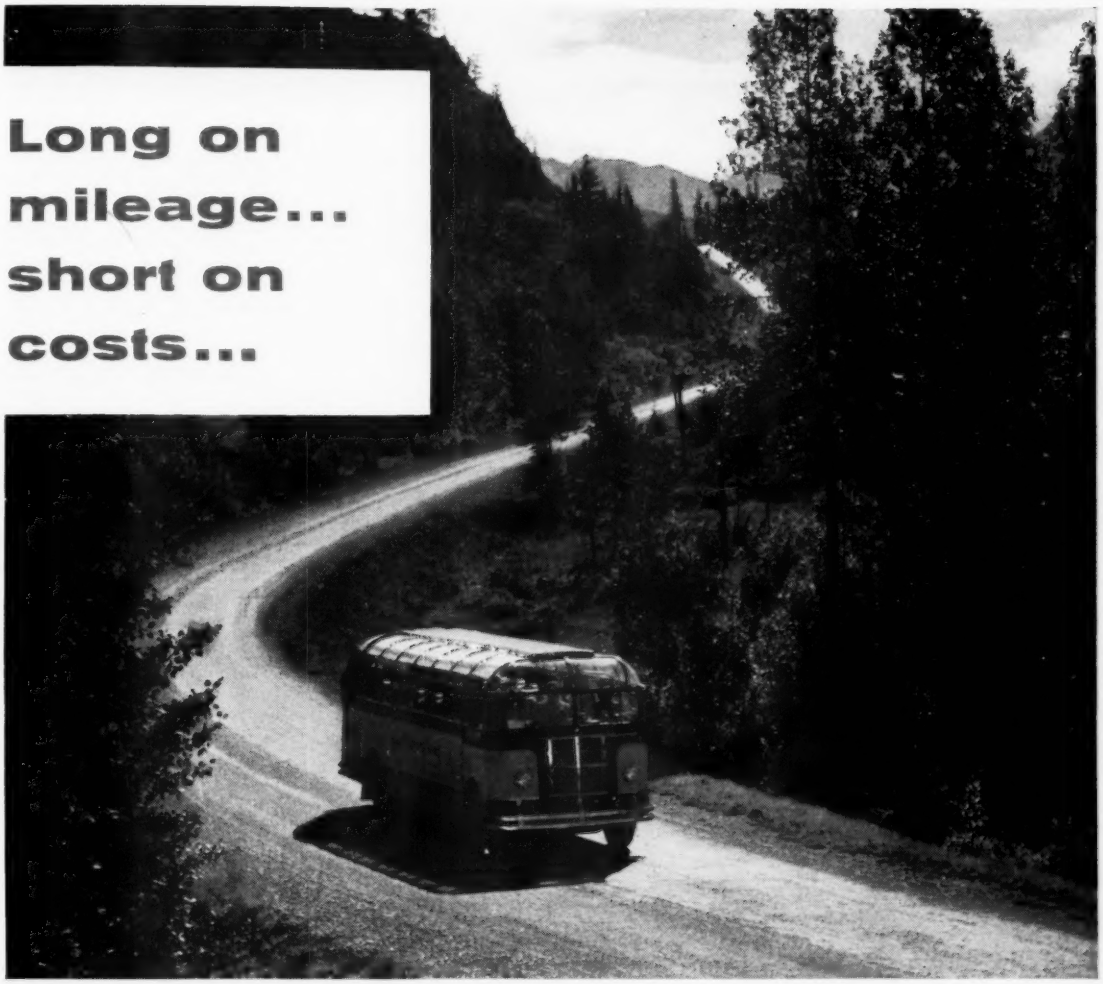

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